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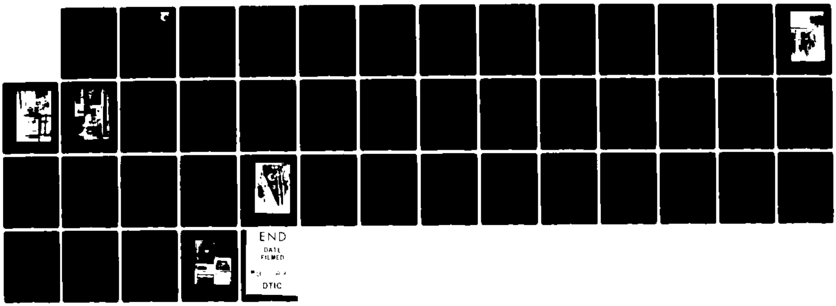

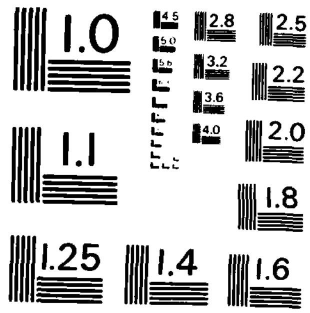

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COMBINED ENVIRONMENT TEST OF SANGAMO WESTON SABRE XII AIRBORNE RECORDER

Preston S. Hall
Gerald A. Plzak

Environmental Control Branch
Vehicle Equipment Division

June 1983

Final Report for Period February 1982 - March 1982

Approved for public release; distribution unlimited.

FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
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This technical report has been reviewed and is approved for publication.

Preston Scott Hall
Mechanical Engineer
Combined Environments Test Grp

Technical Manager
Vibration Field Test Grp

FOR THE COMMANDER

Solomon R. Metres
SOLOMON R. METRES
Director
Vehicle Equipment Division

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A combined environment test was performed on the Sangamo Weston SABRE XII airborne recorder for reliability evaluation. The recorder was exposed to various flight conditions characteristic of the F-111 flight profiles. It was found that the recorder performed within equipment specifications when exposed to the combined environments.

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FOREWORD

This report describes an in-house effort conducted by personnel of AFWAL/FIEE and AFWAL/FIBG under Project 2401, Task 240104, Work Unit 24010402.

The work reported herein was performed during the period 25 February 1982 to 11 March 1982, under the direction of the authors P. S. Hall and G. A. Plzak who were the joint project engineers. The report was released by the authors in September 1982.

The authors wish to express their appreciation to William (Bill) Kessler and Francis Wosniak of Fairchild Weston Systems, Inc., manufacturer of The Sabre XII Recording/Reproducing Systems for their cooperation and efforts in this program.

Also, sincere appreciation is given to Mike Fabian and Carl Williams (FIEE), the CERT operating team.

The efforts of Earl Rogers for his painstaking Data Recording and Mike Banford (FIBG) for his help in after hours Data Playback are also appreciated.

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SECTION I

INTRODUCTION

1. PURPOSE OF REPORT

This report presents the results of Combined Environment Reliability Tests (CERT) on the Sangamo Sabre XII airborne recorder. The recording capability of the SABRE XII was verified for simulated FB-111 flight environments. This is documented by raw and analyzed High Density Digital Data recorded during the simulated flight environments.

2. BACKGROUND

Reliability of flight test data recorders should be as high as possible to avoid duplication of expensive test flights due to poor data. The Structural Vibration Branch of the Air Force Wright Aeronautical Laboratories, AFWAL/FIBG, performs numerous flight measurement programs for various Air Force customers and requires airborne recorders with high density digital data recording capabilities. The Sangamo SABRE XII airborne recorder was selected as a possible recorder for AFWAL/FIBG's use. It was decided to verify that the unit could withstand and function under flight environments using the CERT facility at AFWAL/FIEE, Wright-Patterson AFB, Ohio.

Simulated FB-111 environmental mission profiles and test conditions correlated to previous flight test programs were chosen to represent field conditions. Sangamo representatives provided the test recorder and support equipment to generate input data and monitor performance during the test. AFWAL/FIBG analyzed the recorder tape after each mission.

SECTION II

DESCRIPTION OF SABRE XII RECORDER

The SABRE XII is designed for data acquisition during flight tests, or any other mobile application. It is an Inter-range Instrumentation Group (IRIG) format High Density Digital Record (HDDR), FM or Direct Recorder with 8 speed capability 7, 14,and 28 channel configurations for 1/2" or 1" tape are provided.

The SABRE XII system consists of recorder, electronics box, control unit, and ground test unit.

The recorder can be controlled from remote position by the control unit which provides single button pretest and multi-function failure alarm. For field test and calibration purposes, the ground test unit includes three channels of reproduction electronics and an oscilloscope.

SECTION III

TEST FACILITY AND SETUP

This section describes the test setup for the combined environment test of the SABRE XII. It includes a description of the test chamber, the test installation, and instrumentation used to monitor and analyze test data.

1. TEST FACILITY

The SABRE XII was tested in a facility developed for aircraft mission profile simulation tests. This is the CERT III facility at the Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio. CERT III consists of a 5' x 5' x 5' test chamber with a capability for combined simulation of aircraft compartment temperature, altitude, humidity and random vibration. The CERT III also includes controlled cooling air capability (airflow rate, temperature, and humidity). The facility was developed to provide ranges and response rates comparable to or exceeding measured flight environmental conditions.

The test facility utilizes an externally located airflow conditioning system utilizing mechanical refrigeration and electrical heating. Cooling air is controlled from $-65^{o}F$ to $+160^{o}F$ at a temperature change rate of $120^{o}F$ per minute and an airflow rate up to 15 pounds per minute. Humidity is supplied in the cooling and airflow by a steam generator. The humidity is variable from 0.00001 pound of water per pound of dry air to full saturation. The altitude (pressure) capability simulates altitudes to 70,000 feet (0.65 psia) with change rate of +10,000 feet per minute ascending and -20,000 feet per minute descending.

A Ling B335 shaker is positioned so that its head penetrates into the chamber. The shaker is digitally controlled and provides a five to 2000 Hertz frequency range with either sine or random wave form input. The shaker/chamber interface is accomplished by a vibration fixture that penetrates the chamber floor and is sealed to prevent air leakage.

Vibration is controlled automatically by a digital computer controller. This system provides simulated aircraft vibration spectra which vary throughout the mission. Appendix A gives a more detailed description of the controller.

To achieve a precisely controlled environment around the test specimen, a smaller control volume is formed by using a shroud within the test chamber. The shroud fits over the test specimen and around the test fixture. Conditioned air flows into a plenum on top of the shroud, is distributed evenly throughout the shroud by multiple injection tubes, and escapes to the chamber.

2. TEST ITEM INSTALLATION

The Sabre XII recorder and record electronics box were mounted in the test chamber on their respective mounting racks, Figure 1. The remote control unit and ground test unit were located external to the test chamber, and were connected electrically to the recorder and electronics through the chamber walls (Figure 2).

3. TEST EQUIPMENT SETUP

Two sets of ground test equipment were required to input data to the SABRE XII recorder and reproduce the data at the end of the mission. During the record process, a Coded Communications bit error test set was used to generate an "NRZ-L 2" bit pseudo random word which was recorded at 27 K bits/inch on Ampex 799 tape (tracks 1, 3, 11, 13, 15, and 17). Recorded data was reproduced in the laboratory utilizing the Honeywell Model 96 and direct electronics at reproduce speeds of 30 or 60 ips. The clock and NRZ-L data were then reconstructed from the recorder analog output using an EMR 740 BIT Synchronizer. Finally, errors were measured with an EMR 721 BIT Error test set (Figure 3). One channel of data could be analyzed per pass. Although data for this test was recorded on multiple tracks, only tracks 3, 13, and 15 were normally tested for errors.

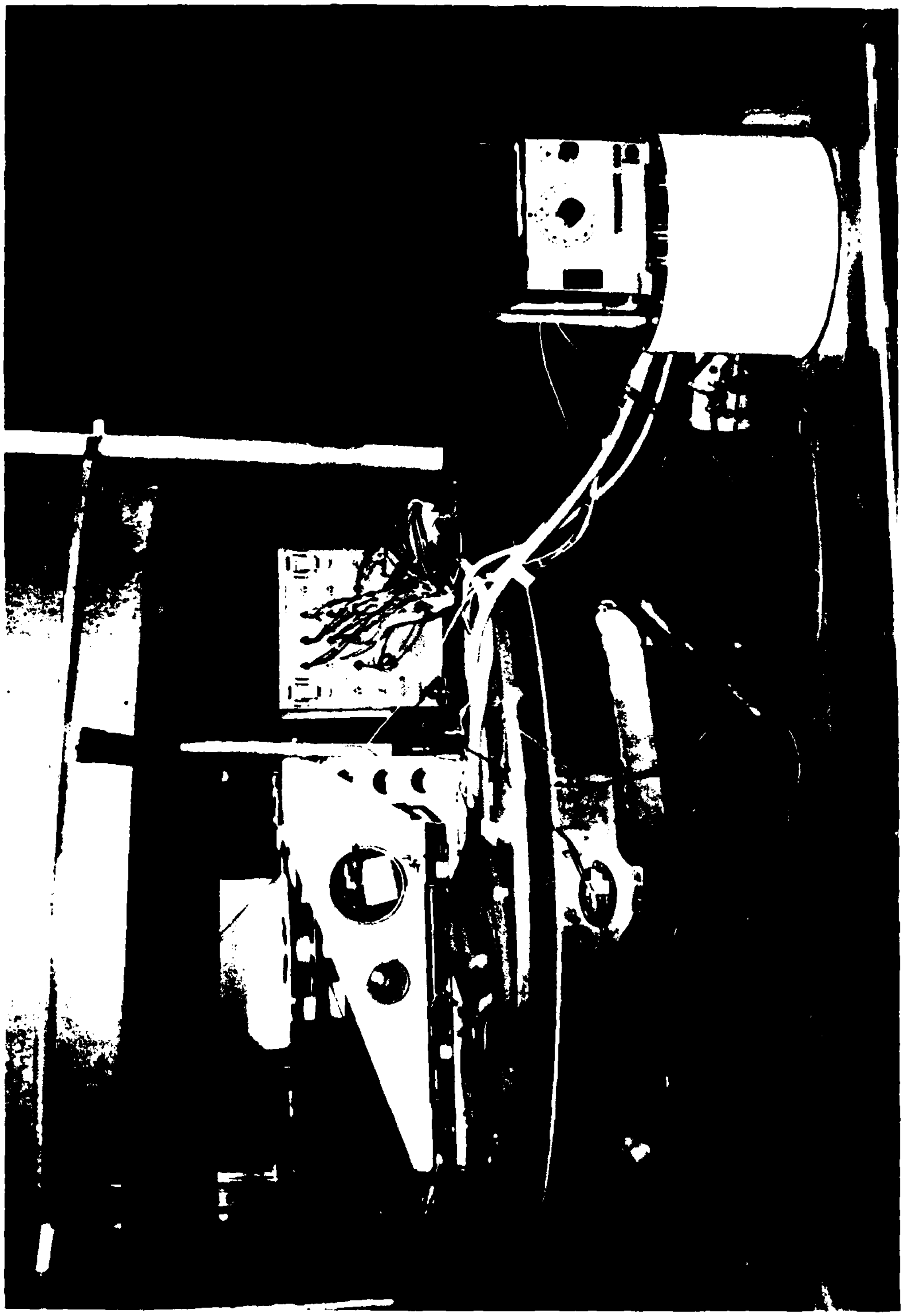

Figure 1. Test Item with Shroud in Raised Position

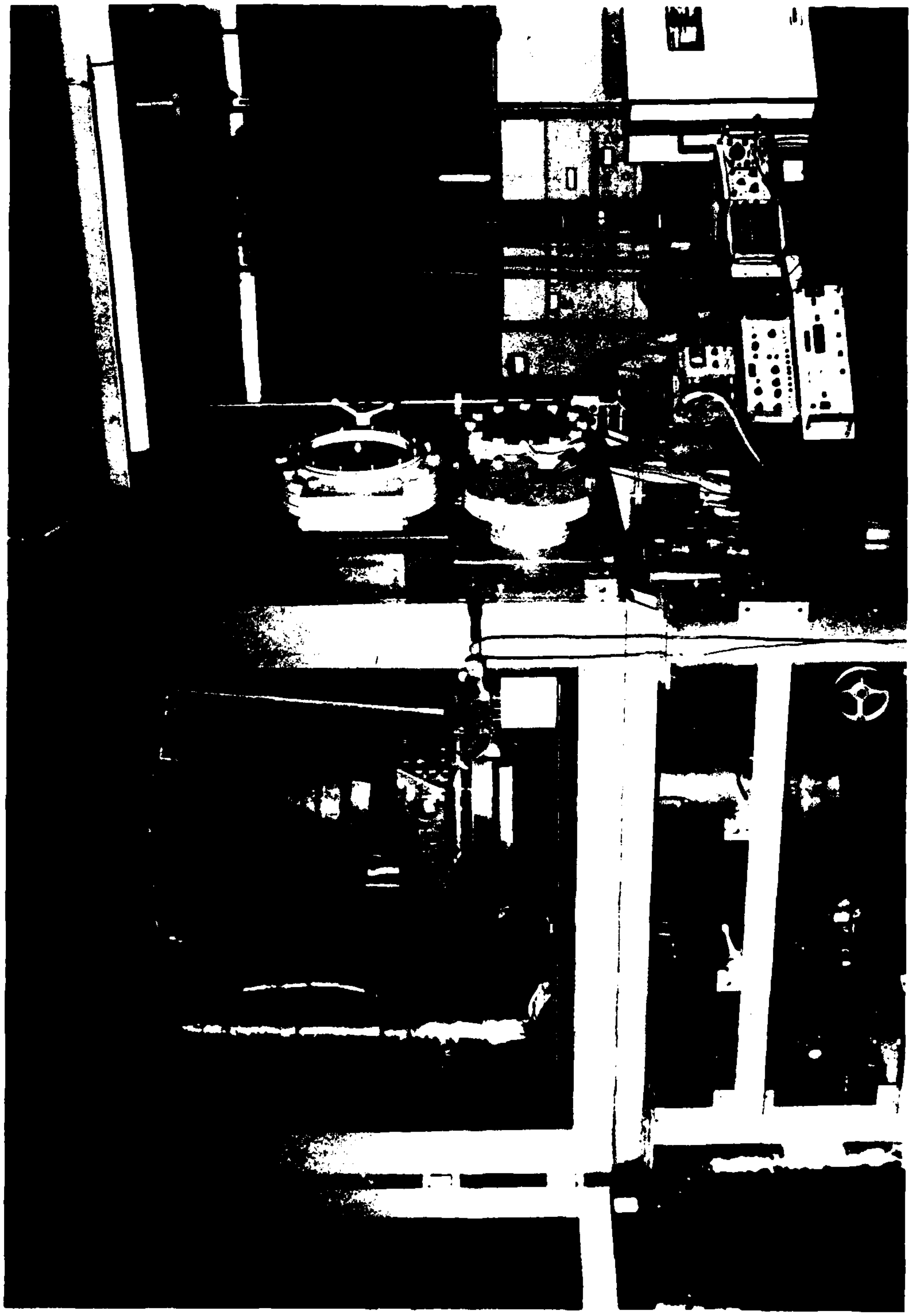

Figure 2. Test Chamber and Ground Test Equipment

Figure 3. Ground Test Equipment

SECTION IV

TEST PLAN

This section describes development of the mission profiles and environmental stresses, procedures for conducting the test, and reasons for conducting the test in this manner.

1. MISSION PROFILE SELECTION

The Sangamo SABRE XII airborne tape recorder is a potential flight test recorder for use on various aircraft. The FB-111 aircraft mission profile was selected as representative of test aircraft. Measured flight data was available and past experience from other CERT tests existed for profile development.

In previous CERT testing of FB-111 equipment, strategic bombing mission and instrument/training missions were predominantly used. The instrument/training mission was chosen for this test because of the dynamic environmental requirements. Figure 4 is the average mission profile depicting engine RPM, MACH number, and altitude variations with respect to mission time.

2. ENVIRONMENTAL PROFILE DEVELOPMENT

The test profiles consist of environmental stresses representing temperature, altitude, humidity, vibration, and equipment on/off cycling. Measured flight data for the instrument/training mission was used to develop environmental stresses which simulate the conditions that the SABRE XII could experience in the forward avionics bay of the FB-111.

The bay thermodynamic conditions were determined by computer analysis based upon the mission profile parameters. This program computes the bay temperature, pressure, and dew point temperature for given inputs of engine RPM, altitude, MACH number, flight time, and atmospheric condition. The result of this analysis is shown in Figures 5 through 8 and in Tables 1 and 2. The selected atmospheres used for the thermal analysis were taken from MIL-STD-210A cold and hot climates.

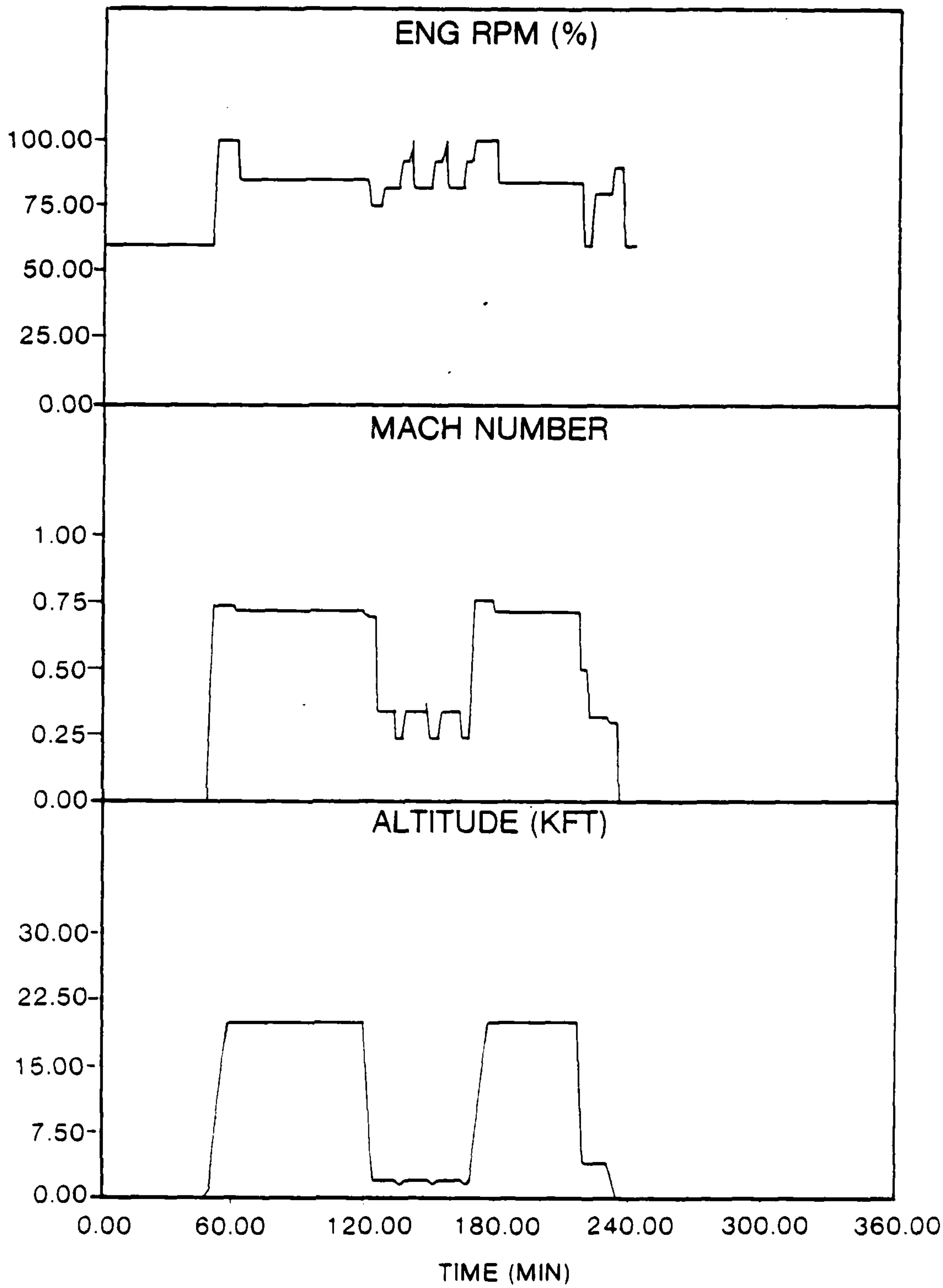

Figure 4. F-111 Mission Profile

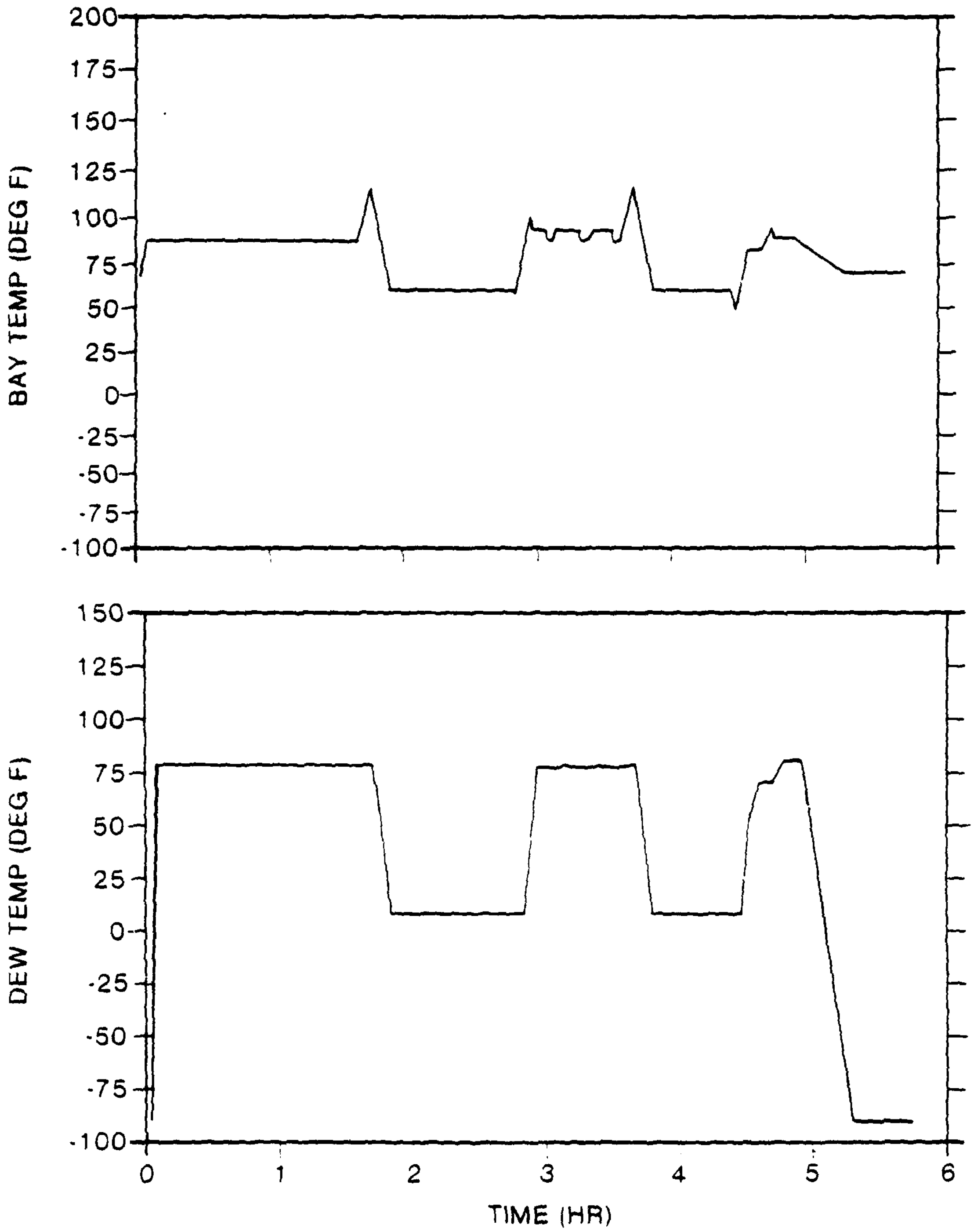

Figure 5. Humidity and Temperature Profiles (Hot Mission)

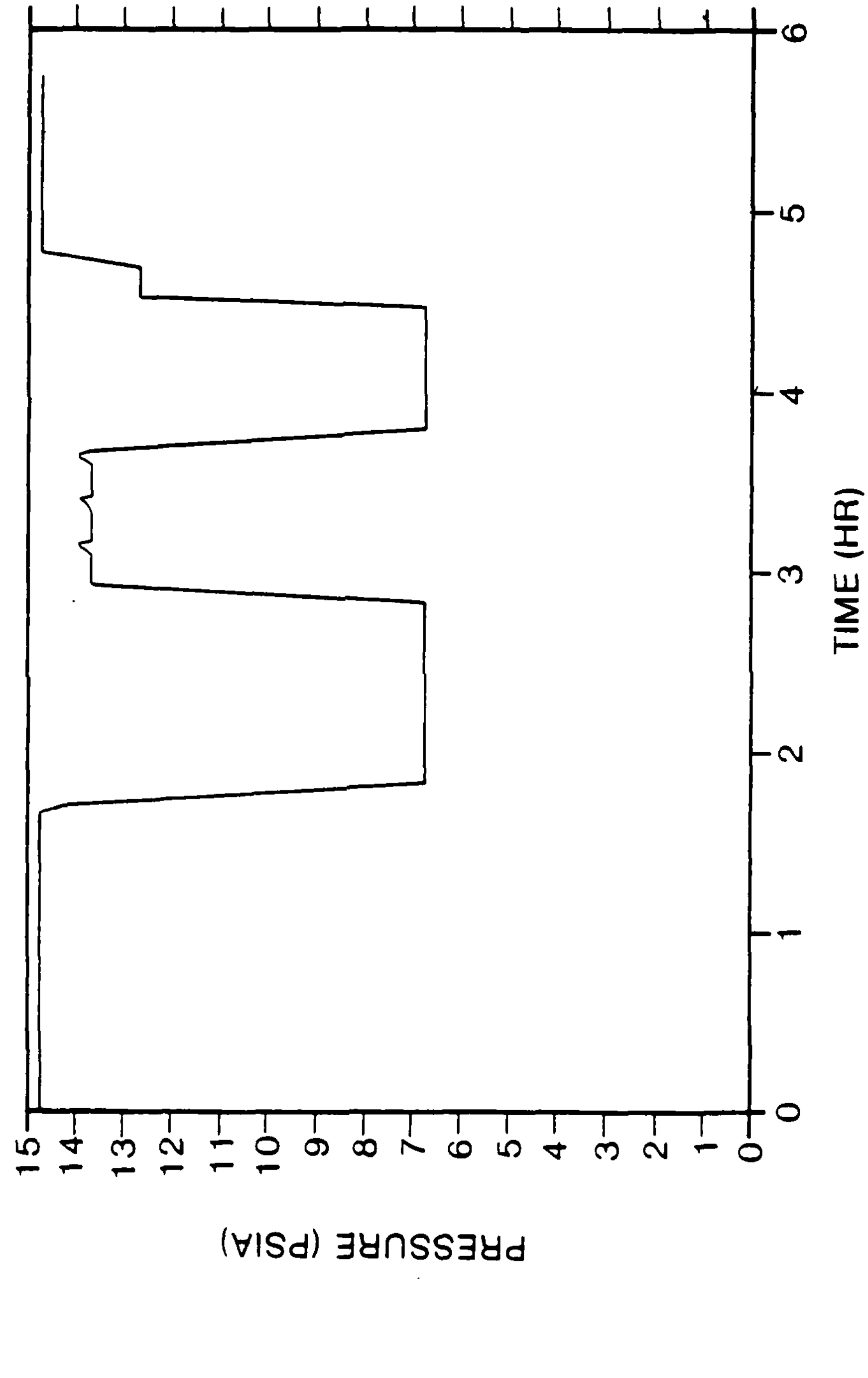

Figure 6. Altitude Profile (Hot Mission)

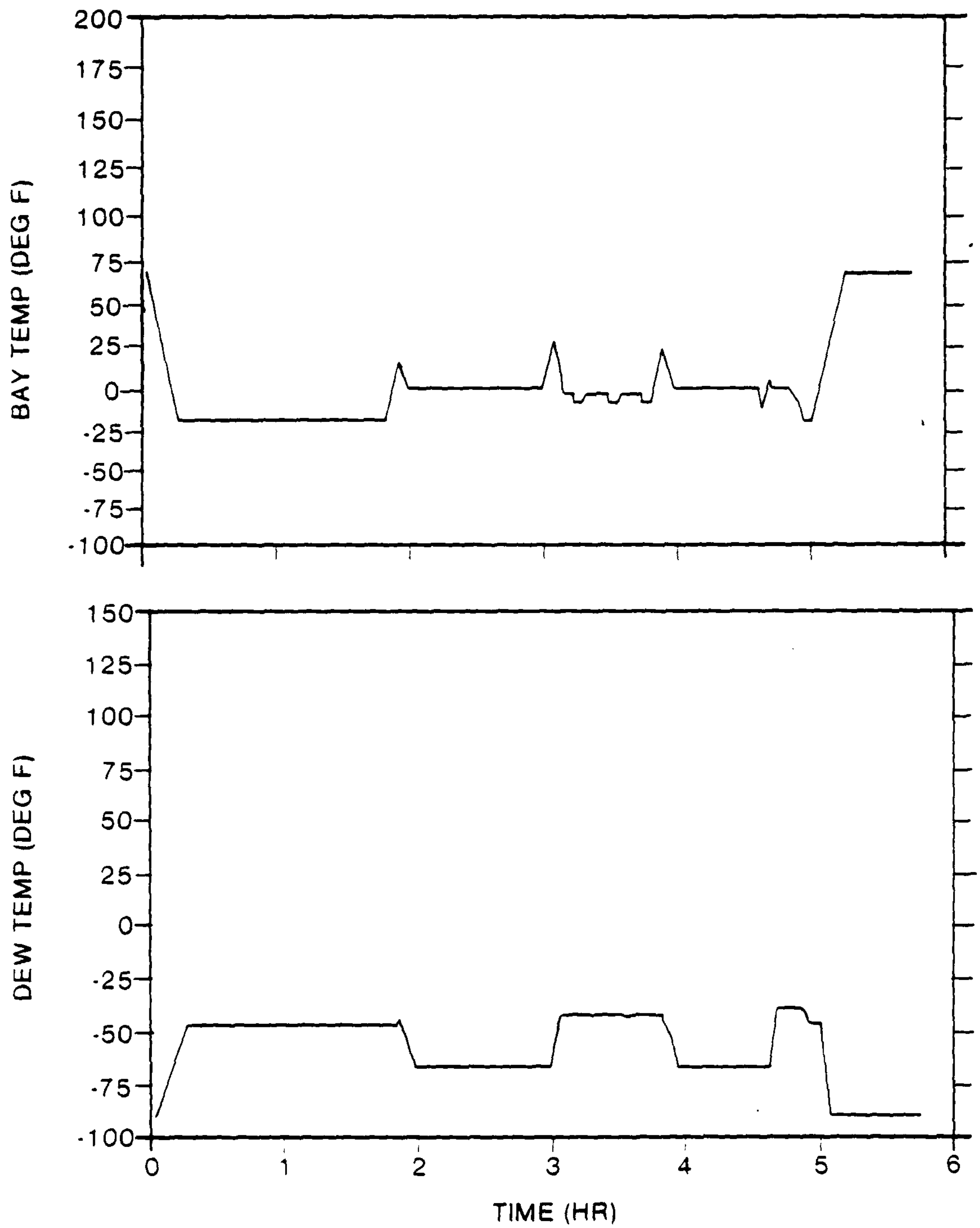

Figure 7. Humidity and Temperature Profiles (Cold Mission)

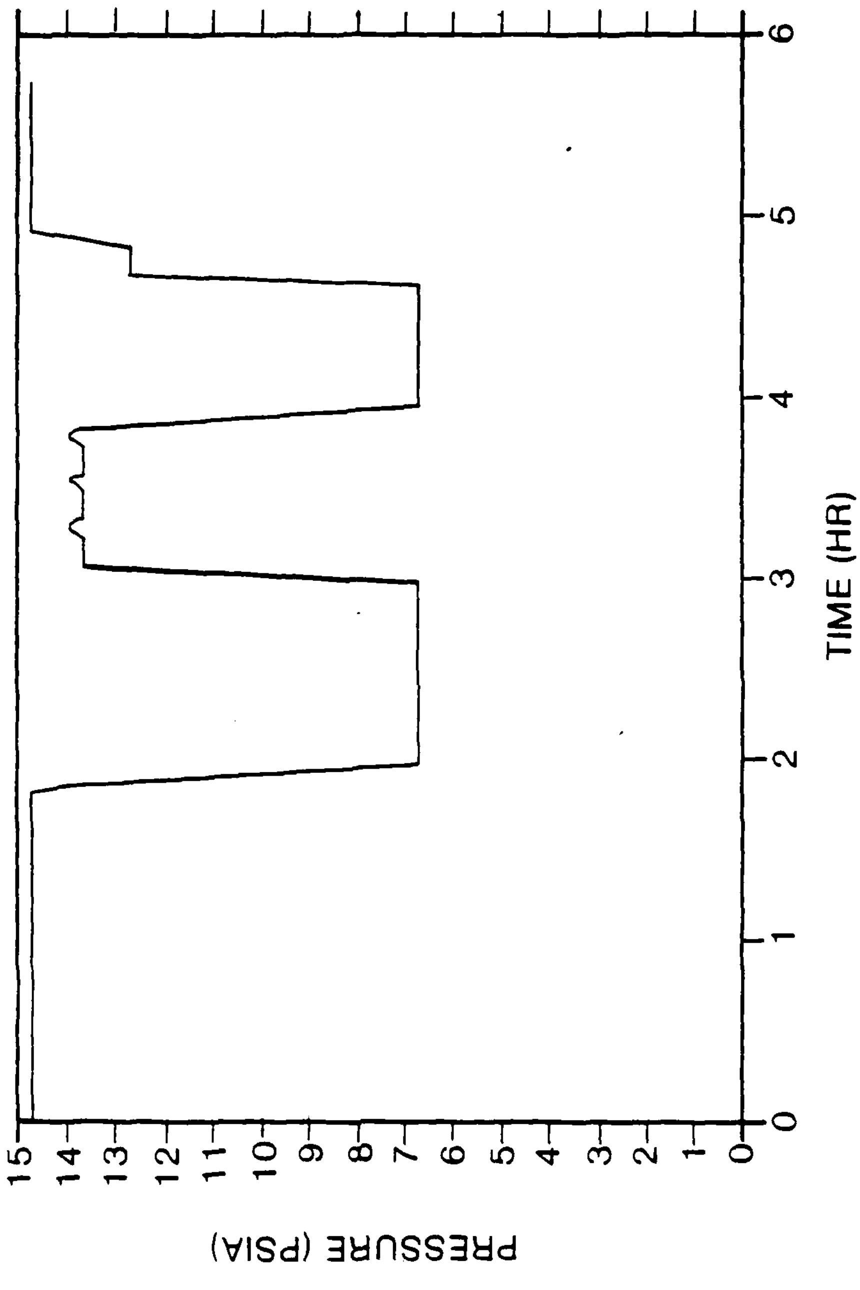

Figure 8. Altitude Profile (Cold Mission)

TABLE 1

COLD MISSION PROFILE BREAK POINTS

Pt.	TIME	ALTITUDE		PRESSURE		BAY TEMP		DEW TEMP	
	MIN	KM	KFT	KPA	PSI	C	F	C	F
1	0.0	-0.0	-0.0	101.4	14.7	21	70	-68	-90
2	2.0	-0.0	-0.0	101.4	14.7	21	70	-68	-90
3	16.0	-0.0	-0.0	101.4	14.7	-27	-16	-44	-47
4	109.0	-0.0	-0.0	101.4	14.7	-27	-16	-44	-47
5	110.0	0.2	0.5	99.5	14.4	-23	-10	-43	-46
6	111.0	0.3	1.0	97.7	14.2	-20	-4	-42	-44
7	113.0	1.2	4.1	87.2	12.6	-14	6	-45	-49
8	115.0	2.7	9.0	72.5	10.5	-7	20	-48	-55
9	119.0	6.1	20.0	46.6	6.8	-14	6	-55	-67
10	120.0	6.1	20.0	46.6	6.8	-16	3	-55	-67
11	178.0	6.1	20.0	46.6	6.8	-16	3	-55	-67
12	179.0	6.1	20.0	46.6	6.8	-17	1	-55	-67
13	184.0	0.6	2.0	94.2	13.7	-1	31	-41	-42
14	185.0	0.6	2.0	94.2	13.7	-3	26	-41	-42
15	187.0	0.6	2.0	94.2	13.7	-9	16	-41	-42
16	189.0	0.6	2.0	94.2	13.7	-18	0	-41	-42
17	193.0	0.6	2.0	94.2	13.7	-18	0	-41	-42
18	194.0	0.6	2.0	94.2	13.7	-21	-5	-41	-42
19	197.0	0.5	1.5	96.0	13.9	-21	-6	-42	-43
20	198.0	0.5	1.5	96.0	13.9	-18	-1	-42	-43
21	199.0	0.6	2.0	94.2	13.7	-18	0	-41	-42
22	208.0	0.6	2.0	94.2	13.7	-18	0	-41	-42
23	209.0	0.6	2.0	94.2	13.7	-21	-5	-41	-42
24	213.0	0.5	1.5	96.0	13.9	-21	-6	-42	-43
25	214.0	0.6	2.0	94.2	13.7	-18	0	-41	-42
26	215.0	0.6	2.0	94.2	13.7	-18	0	-41	-42
27	223.0	0.6	2.0	94.2	13.7	-18	0	-41	-42
28	224.0	0.6	2.0	94.2	13.7	-21	-5	-41	-42
29	227.0	0.5	1.5	96.0	13.9	-21	-6	-42	-43
30	228.0	0.5	1.5	96.0	13.9	-18	-1	-42	-43
31	229.0	0.6	2.0	94.2	13.7	-15	5	-41	-42
32	231.0	1.6	5.3	83.4	12.1	-9	16	-44	-48
33	233.0	2.7	8.7	73.3	10.6	-3	26	-47	-53
34	237.0	6.1	20.0	46.6	6.8	-13	8	-55	-67
35	238.0	6.1	20.0	46.6	6.8	-16	3	-55	-67
36	276.0	6.1	20.0	46.6	6.8	-16	3	-55	-67
37	277.0	6.1	20.0	46.6	6.8	-19	-3	-55	-67
38	278.0	4.4	14.3	58.9	8.5	-22	-8	-50	-58
39	280.0	1.2	4.0	87.5	12.7	-16	4	-39	-39
40	281.0	1.2	4.0	87.5	12.7	-14	6	-39	-39
41	282.0	1.2	4.0	87.5	12.7	-16	3	-39	-39
42	289.0	1.2	4.0	87.5	12.7	-16	3	-39	-39
43	290.0	1.2	4.0	87.5	12.7	-17	2	-39	-39
44	294.0	0.3	1.0	97.7	14.2	-21	-5	-42	-44
45	295.0	-0.0	-0.0	101.3	14.7	-24	-11	-44	-47
46	296.0	-0.0	-0.0	101.3	14.7	-27	-16	-44	-47
47	300.0	-0.0	-0.0	101.3	14.7	-27	-16	-44	-47
48	305.0	-0.0	-0.0	101.3	14.7	-10	14	-68	-90
49	315.0	-0.0	-0.0	101.4	14.7	21	70	-68	-90
50	345.0	-0.0	-0.0	101.4	14.7	21	70	-68	-90

TABLE 2

HOT MISSION PROFILE BREAK POINTS

Pt.	TIME MIN	ALTITUDE KM	ALTITUDE KFT	PRESSURE KPA	PRESSURE PSI	BAY TEMP C	BAY TEMP F	DEW TEMP C	DEW TEMP F
1	0.0	-0.0	-0.0	101.4	14.7	21	70	-68	-90
2	2.0	-0.0	-0.0	101.4	14.7	21	70	-68	-90
3	5.0	-0.0	-0.0	101.4	14.7	32	90	26	79
4	6.0	-0.0	-0.0	101.4	14.7	32	90	26	79
5	41.0	-0.0	-0.0	101.4	14.7	32	90	26	79
6	51.0	-0.0	-0.0	101.4	14.7	32	90	26	79
7	100.0	-0.0	-0.0	101.4	14.7	32	90	26	79
8	101.0	0.2	0.5	99.5	14.4	36	96	26	79
9	102.0	0.3	1.0	97.7	14.2	39	102	26	79
10	103.0	1.1	3.5	89.2	12.9	43	110	19	67
11	105.0	1.8	6.0	81.2	11.8	47	117	13	56
12	110.0	6.1	20.0	46.6	6.8	29	85	-13	8
13	111.0	6.1	20.0	46.6	6.8	26	79	-13	8
14	114.0	6.1	20.0	46.6	6.8	16	61	-13	8
15	169.0	6.1	20.0	46.6	6.8	16	61	-13	8
16	170.0	6.1	20.0	46.6	6.8	15	59	-13	8
17	175.0	0.6	2.0	94.2	13.7	32	89	25	77
18	176.0	0.6	2.0	94.2	13.7	35	95	25	77
19	177.0	0.6	2.0	94.2	13.7	38	101	25	77
20	178.0	0.6	2.0	94.2	13.7	34	94	25	77
21	184.0	0.6	2.0	94.2	13.7	34	94	25	77
22	185.0	0.6	2.0	94.2	13.7	31	88	25	77
23	188.0	0.5	1.5	96.0	13.9	32	90	26	78
24	189.0	0.5	1.5	96.0	13.9	36	96	26	78
25	190.0	0.6	2.0	94.2	13.7	34	94	25	77
26	199.0	0.6	2.0	94.2	13.7	34	94	25	77
27	200.0	0.6	2.0	94.2	13.7	31	88	25	77
28	204.0	0.5	1.5	96.0	13.9	32	90	26	78
29	205.0	0.6	2.0	94.2	13.7	34	94	25	77
30	206.0	0.6	2.0	94.2	13.7	34	94	25	77
31	214.0	0.6	2.0	94.2	13.7	34	94	25	77
32	215.0	0.6	2.0	94.2	13.7	31	88	25	77
33	218.0	0.5	1.5	96.0	13.9	32	90	26	78
34	219.0	0.5	1.5	96.0	13.9	36	96	26	78
35	220.0	0.6	2.0	94.2	13.7	39	102	25	77
36	222.0	1.5	4.8	84.8	12.3	44	112	18	64
37	223.0	2.1	6.8	78.9	11.4	48	118	13	55
38	228.0	6.1	20.0	46.6	6.8	29	85	-13	8
39	229.0	6.1	20.0	46.6	6.8	25	79	-13	8
40	232.0	6.1	20.0	46.6	6.8	16	61	-13	8
41	267.0	6.1	20.0	46.6	6.8	16	61	-13	8
42	268.0	6.1	20.0	46.6	6.8	13	55	-13	8
43	269.0	4.5	14.7	57.8	8.4	10	50	-4	25
44	271.0	1.2	4.0	87.5	12.7	17	63	12	53
45	272.0	1.2	4.0	87.5	12.7	21	69	15	59
46	275.0	1.2	4.0	87.5	12.7	29	85	21	70
47	280.0	1.2	4.0	87.5	12.7	29	85	21	70
48	281.0	1.2	4.0	87.5	12.7	29	84	21	70
49	285.0	0.3	1.0	97.7	14.2	35	95	26	78
50	286.0	-0.0	-0.0	101.3	14.7	32	90	27	80
51	291.0	-0.0	-0.0	101.3	14.7	32	90	27	80
52	295.0	-0.0	-0.0	101.3	14.7	32	90	27	80
53	313.0	-0.0	-0.0	101.3	14.7	21	70	-68	-90
54	345.0	-0.0	-0.0	101.3	14.7	21	70	-68	-90

The vibration spectra used for this test were derived from a computer prediction technique, Reference 1, and then correlated with measured F-111 flight data. Two different vibration spectra were developed. One spectrum is representative of Straight-and Level Cruise, Figure 9, and the other is representative of Take-off or Combat, Figure 10.

The SABRE XII on/off cycling was initially established based on hypothesized flight test operations. No power was to be applied to the recorder until an hour into the mission. At this time power would be turned on. Ten minutes later a functional check would be performed. This was later changed when it was determined to be unrealistic. Power was applied after the soak temperature was achieved, 16 minutes into the mission, and remained on throughout the mission. Tables 3 and 4 show the schedule of record times with respect to the vibration schedule, since vibration would be the primary mission parameter to mark events during a flight test.

3. ENVIRONMENTAL TEST PROFILE SEQUENCE

The climatic conditions selected for analysis were taken from MIL-STD-210A, Reference 2. Two missions were developed; one for cold climate and one for hot climate. Both missions were five hours and five minutes in length. The cold mission had an hour and forty-nine minute cold soak before take-off, while the hot mission had an hour and forty minute hot soak before take-off. Tables 3 through 6 show the test schedules for both cycles at the various tape speeds. Data was acquired at maximum (120 ips) and minimum (1-7/8 ips) tape speeds for both hot and cold missions. A program goal was to accumulate at least two cycles of each mission at each tape speed or eight cycles totaling approximately 40 hours.

4. PRE-TEST CHECKOUT

Before the actual test started, certain checkout procedures and special tests were performed on both facility and SABRE XII systems. These tests are described herein.

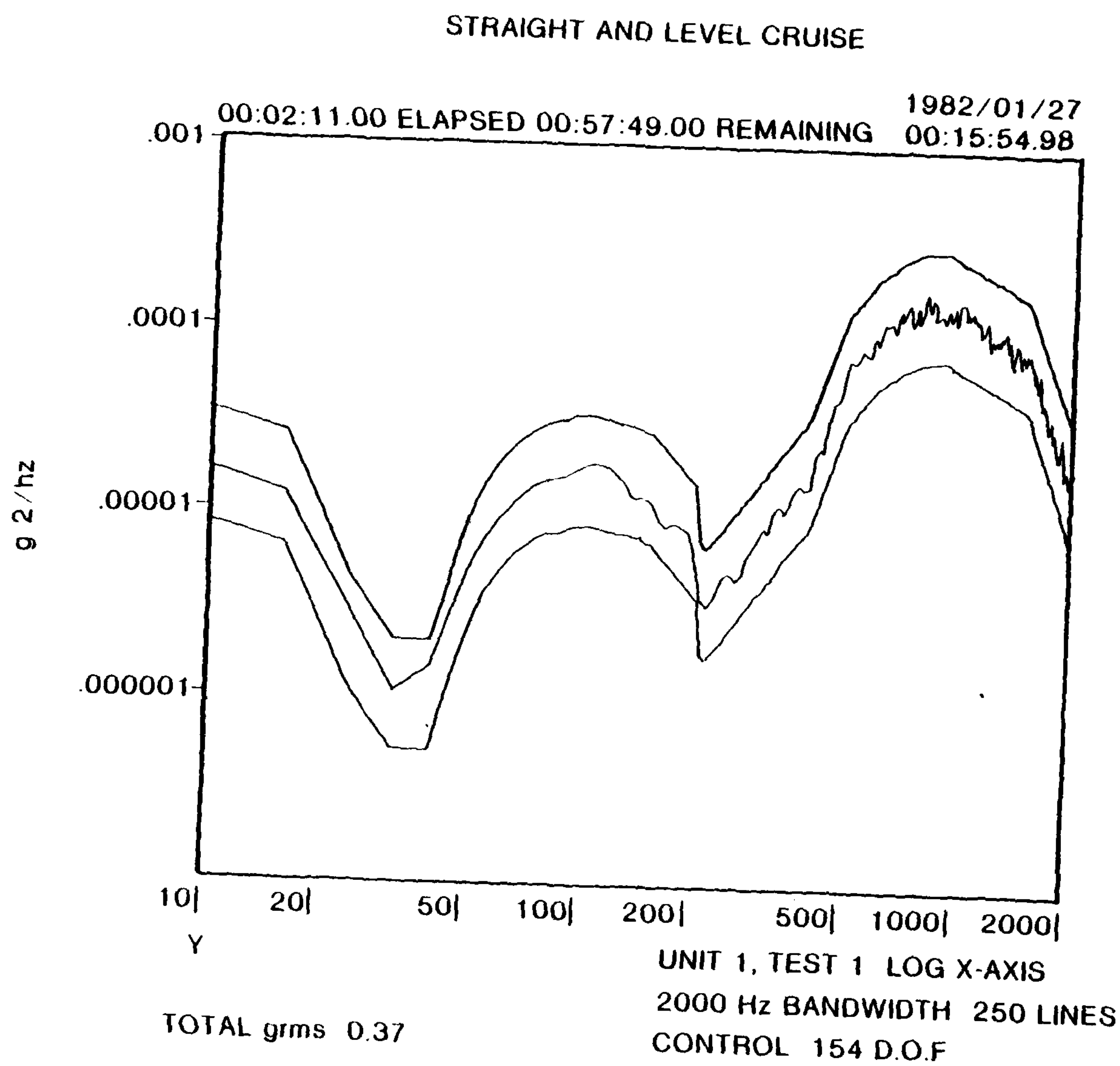

Figure 9. Flight Recorder Test Spectrum

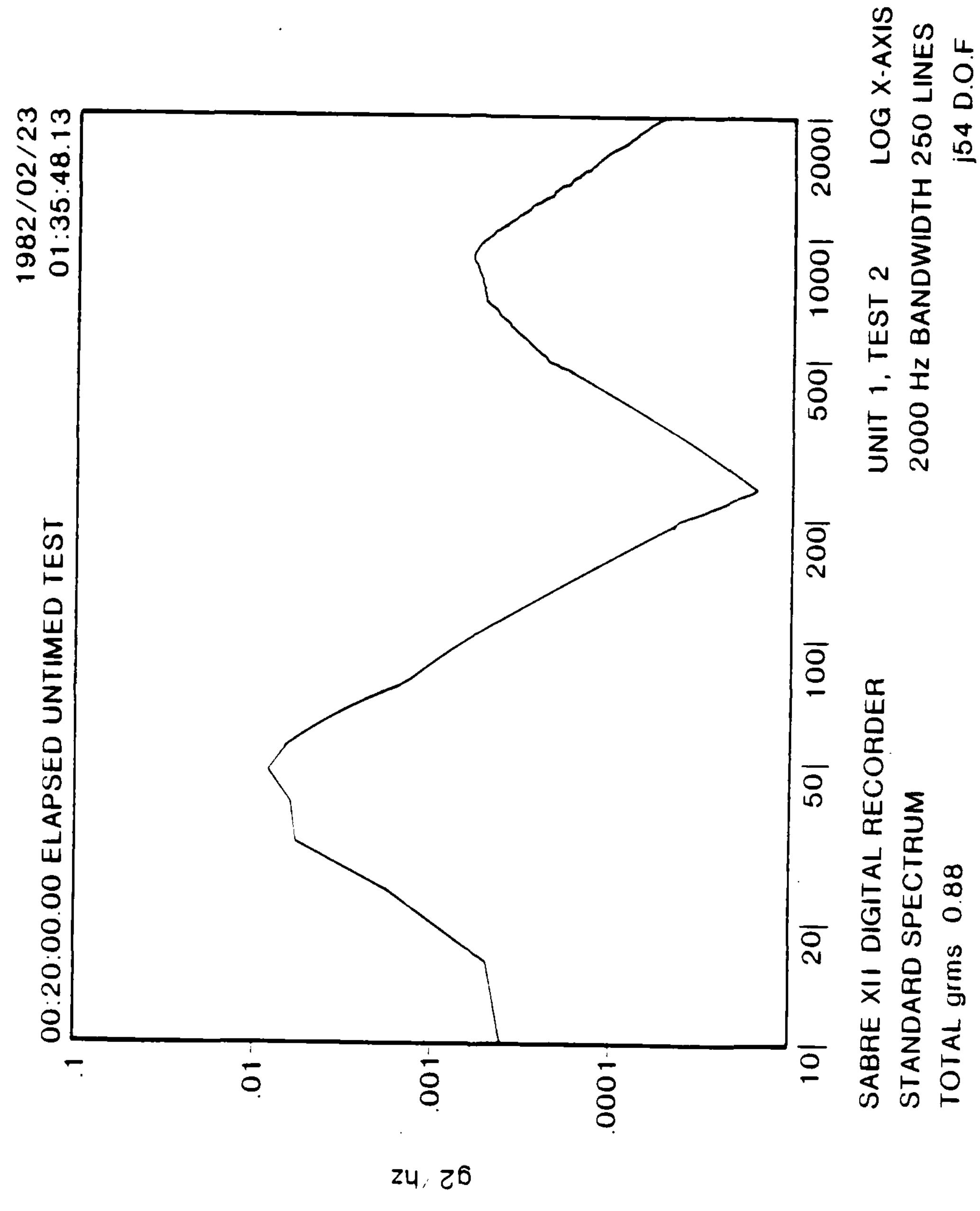

Figure 10. Flight Recorder Test Buffet Condition

TABLE 3

TEST SCHEDULE FOR RECORDER

1-7/8 IPS HOT MISSION

Test	Time	
0	0	Start HOT soak ramp
0	16	Start HOT soak
0	60	Turn recorder on/stby
1	20	Turn recorder on record
1	40	Start take-off phase
1	50	Start cruise phase
2	50	Start descent phase
2	55	Start Low Altitude (L/A)
3	05	Start combat phase
3	10	Resume L/A cruise
3	20	Resume combat
3	25	Resume L/A cruise
3	35	Resume combat
3	48	Resume High Altitude (H/A)
4	27	Start landing phase
4	47	Landing completed
4	48	Turn recorder off
4	58	End of mission

TABLE 4

TEST SCHEDULE FOR RECORDER

1-7/8 IPS COLD MISSION

Test	Time	
0	0	Start COLD soak ramp
0	16	Start COLD soak
0	60	Turn recorder on/stby
1	20	Turn recorder on record
1	40	Start take-off phase
1	50	Start cruise phase
2	50	Start descent phase
2	55	Start Low Altitude (L/A)
3	05	Start combat phase
3	10	Resume L/A cruise
3	20	Resume combat
3	25	Resume L/A cruise
3	35	Resume combat
3	48	Resume High Altitude (H/A)
4	27	Start landing phase
4	47	Landing completed
4	48	Turn recorder off
4	58	End of mission

TABLE 5

TEST SCHEDULE FOR RECORDER

120 IPS HOT MISSION

Test Time		
Hr	Min	
0	0	start of hot soak ramp
0	16	start of hot soak
0	60	turn recorder on/stby
1	10	pre flight test
1	40	start take-off phase
1	42	turn recorder on
1	44	turn recorder off
1	50	start cruise phase
2	50	start descent phase
2	55	start low altitude (L/A)
2	56	turn recorder on
2	57	turn recorder off
3	05	start combat phase
3	10	resume L/A cruise
3	20	resume combat
3	25	resume L/A cruise
3	35	resume combat
3	48	resume high altitude (H/A)
3	49	record on
3	50	record off
4	27	start landing phase
4	28	recorder on
4	30	recorder off
4	47	landing completed
4	58	end of mission

TABLE 6

TEST SCHEDULE FOR RECORDER

120 IPS COLD MISSION

Hr	Min	
0	0	start of cold soak ramp
0	16	start of cold soak
0	60	turn recorder on/stby
1	10	pre flight test
1	49	start take-off phase
1	51	turn recorder on
1	53	turn recorder off
1	59	start cruise phase
2	59	start descent phase
2	64	start low altitude (L/A)
3	05	turn recorder on
3	06	turn recorder off
3	14	start combat phase
3	19	resume L/A cruise
3	29	resume combat
3	34	resume L/A cruise
3	44	resume combat
3	57	resume high altitude (H/A)
3	58	recorder on
3	59	recorder off
4	36	start landing phase
4	49	turn recorder on
4	51	turn recorder off
4	54	landing completed
5	05	end of mission

a. Chamber Checkout

The chamber-oriented tests are the normal checkouts conducted before any test. This includes facility checkout, calibration of instruments, profile checks, and trouble shooting. Two thermocouples were used, one for shroud or bay temperature, and the second for recorder internal temperature. The shroud thermocouple, located two to three inches above the recorder, was used as the control.

A number of accelerometers were used for equipment response and input vibration control. Figure 11 shows the response accelerometers and the input monitoring accelerometer.

b. Test Item Checkout

Upon receiving the SABRE XII recorder system, the units were installed in the test chamber and a performance check was conducted under ambient conditions and no vibration. Other performance checks were conducted with varying degrees of combined environments. This allowed the system to be fine tuned and the playback analysis system to be checked for compatibility.

c. Failure Criteria

The test was designed to evaluate the equipment's reliability and quality of performance under combined environments. A failure was defined as a condition which met one or more of the following criteria:

(1) Unscheduled component replacement, repair, or adjustment, except those adjustments which are accessible in flight.

(2) Performance which does not meet the requirements of the design specifications.

5. TEST PROCEDURES

Prior to testing, initial ground rules were established. It was understood that procedures might change during the program, but only upon AFWAL/FIBG's approval.

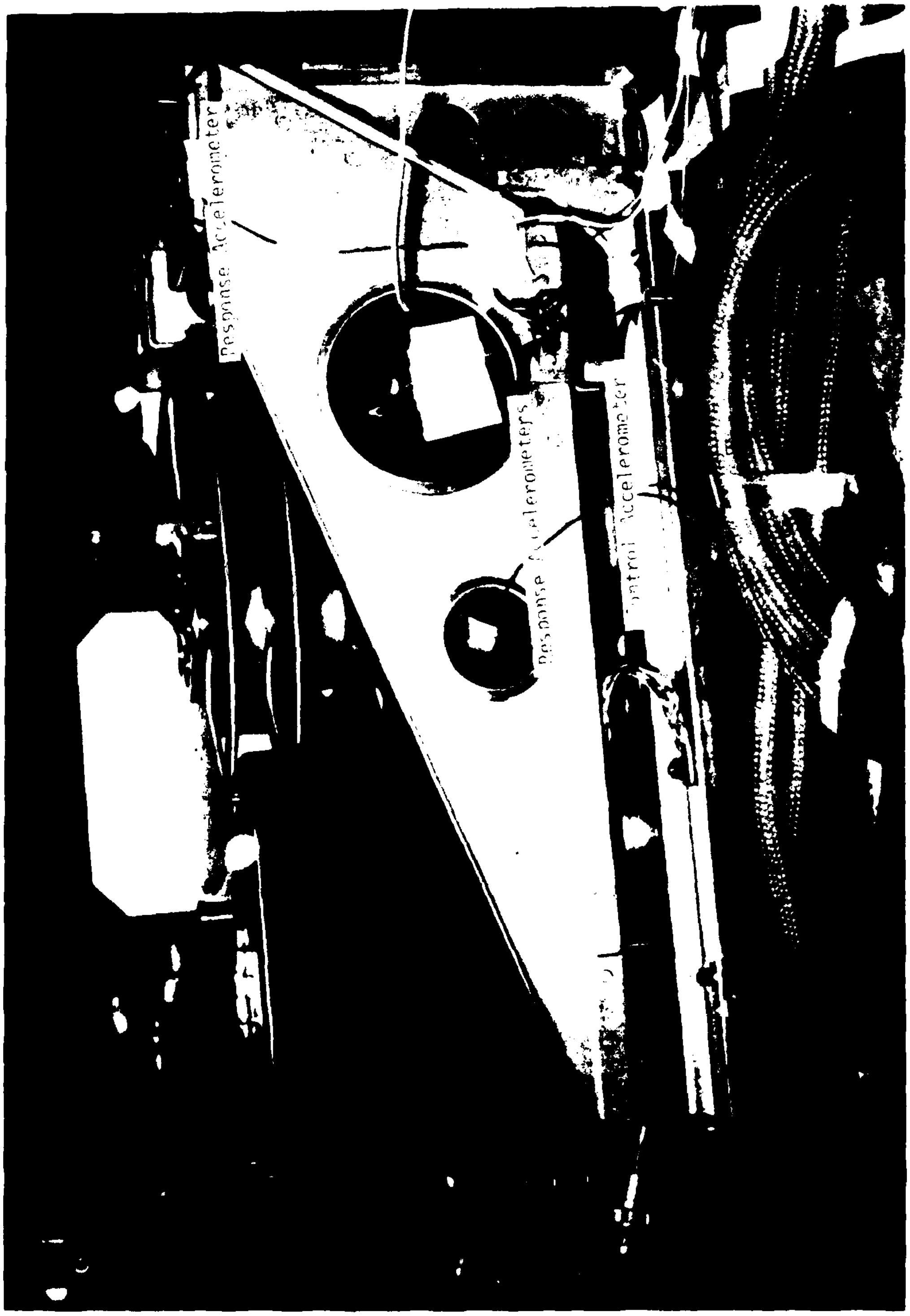

Figure 11. Control and Response Accelerometers

The initial objectives were as follows:

a. Test missions were to alternate hot and cold.

b. At the end of each test mission, the data tape would be removed for analysis and another tape mounted for the next test mission.

c. If the test specimen failed, it could only be removed from the test chamber at the end of the test mission.

d. Test chamber performance parameters were to be monitored throughout the test mission.

e. During payback of a test tape, data errors were to be logged as "total errors" vs. "footage." Final data to be converted to "errors in 1 million bits."

SECTION V

RESULTS AND ANALYSIS

1. TEST SUMMARY

The Sangamo SABRE XII recorder test program consisted of two preliminary and five evaluation tests. The two preliminary tests were to establish the baseline conditions for the hot and cold missions.

There was some concern that the cold was affecting the vibration isolators. Thus, an additional cold cycle was run minus the vibration, but there was no apparent effect.

The combined recorder/reproduce bit error rate with new AMPEX 799 tape was better than the specified limit of one error in one million bits (BER = 1×10^6). Summary data is presented in Tables 7 through 10. The overall BER was 0.16 in one million for 120 ips record speed and 0.12 in one million for 1-7/8 ips. Data reduction was accomplished by computer. Reproduce speeds of 15 to 60 ips were found to be reasonable. The reproduce speed used was originally 30 ips. This was increased to 60 ips to shorten reduction time.

In sub-zero conditions, care must be taken not to subject magnetic tape to prolonged freezing temperatures. The tape manufacture's low limit of $4^{o}C$ is to be respected. This translates into an operational requirement to store the magnetic tape in a heated area until time to load the recorder. The recorder heater must then be used to maintain the tape at a reasonable temperature. Otherwise, large dropouts and a higher BER must be expected. This problem lead to the one cold cycle run without vibration and eventually to changing test procedures.

There were no equipment failures of the SABRE XII. Adjustments were made to the recorder heater to assure that the internal temperature did not fall below the tape temperature requirements of $4^{o}C$.

2. COMPARATIVE ANALYSIS

This section is divided into two parts; analyses of data recorded at 120 ips and data recorded at 1-7/8 ips.

TABLE 7

BER (ERRORS IN 10^6 BITS) FOR EACH MISSION PHASE RECORDED

	HOT MISSION						COLD MISSION						AVERAGE
TRACK	3	3	13	13	15	15	3	3	13	13	15	15	
RUN	1	2	1	2	1	2	1	2	1	2	1	2	
TAKE-OFF	.50	.14	.18	.23	.08	.07	.96	.62	0	0	.08	.01	.24
L.A. CRUISE	.15	.13	0	0	.004	0	.03	.03	0	0	.28	.01	.05
H.A. CRUISE	.01	.04	.02	.02	0	.004	.02	.01	.12	.05	.13	.15	.05
LANDING	.70	.65	.15	.19	0	0	.04	.03	.49	.20	0	0	.20

OVERALL BER = 0.16 ERRORS IN 10^6 BITS

TABLE 8

NUMBER OF ERROR BURSTS FOR EACH MISSION PHASE RECORDED

	HOT MISSION						COLD MISSION						AVERAGE
TRACK	3	3	13	13	15	15	3	3	13	13	15	15	
RUN	1	2	1	2	1	2	1	2	1	2	1	2	
TAKE-OFF	7	7	3	3	1	1	3	5	1	1	3	2	3.1
L.A. CRUISE	4	2	0	0	0	0	3	4	0	0	2	1	1.3
H.A. CRUISE	3	2	2	2	0	1	1	1	4	5	4	3	2.3
LANDING	10	10	3	4	1	0	2	4	1	1	0	0	3.0

TABLE 9

FREQUENCY OF ERRORS

ERROR LENGTH (BITS)	FREQUENCY
1	33
2	13
3	9
4	9
5	4
6-10	8
11-20	9
21-30	9
31-40	3
41-50	3
51-60	2
61-70	2
71-80	3
81-90	0
91-100	1
101-120	0
121-140	1
141-160	1
161-180	2
181-200	2

TABLE 10

BER (ERRORS IN 10^6 BITS) PER 100 FT. @ 1-7/8 ips

	HOT MISSION						COLD MISSION						
TRACK	3	3	13	13	15	15	3	3	13	13	15	15	AVERAGE
RUN	1	2	1	2	1	2	1	2	1	2	1	2	
100-200	.24	.37	0	0	0	0	0	0	.83	.77	0		.20
200-300	.62	.52	.34	.43	.19	.15	0	0	0	0	0		.20
300-400	.15	.15	1.33	.93	.22	.15	0	0	0	0	0		.26
400-500	.06	.22	.12	.19	0	0	0	0	0	0	0		.05
500-600	.22	.22	1.36	1.20	0	0	.06	.06	0	0	0		.28
600-700	.19	.24	.46	.34	0	0	0	0	0	0	0		.11
700-800	.22	.24	.71	.43	0	.06	.06	.15	0	0	0		.19
800-900	.09	.09	.49	.34	0	0	0	.28	0	0	0		.11
900-1000	.15	.12	.24	.25	0	0	.25	0	0	0	.19		.11
1000-1100	.03	.03	.03	0	0	0	0	0	0	0	0		.08
1100-1200	.03	0	0	0	0	0	0	0	0	0	0		.003
1200-1300	0	0	0	0	0	0	.12	0	0	0	0		.11
1300-1400	0	0	0	0	0	0	0	0	0	0	0		0
1400-1500	0	0	.03	0	0	0	0	0	.90	0	0		.08
1500-1600	.06	.12	.46	.06	.06	.06	.71	.59	0	0	0		.19
1600-1700	.12	.34	.68	.59	0	0	0	0	0	0	0		.16
1700-1800	.12	.09	.59	.25	0	0	0	0	0	0	0		.10
1800-1900	.06	.12	.52	.40	0	0	0	0	0	0	0		.10
1900-2000	.06	.06	.03	0	0	0	0	0	0	0	0		.01
2000-2100	.62	.74	0	0	0	0	0	0	0	.18	0		.12

OVERALL BER = 0.12 in 10^6

a. Analysis of Test Results--120 ips

The bit error rates for each of the four flight phases and for two runs of each track are summarized in Table 7. Note that the BER for each flight phase is better than the desired limit of one per million bits. The overall average was only about 0.13 per one million bits.

Table 8 provides a tabulation of the number of error bursts for each flight phase and Table 9 tabulates the frequency of error bursts by length.

The majority of error bursts are in the one to ten bit category. There were six error bursts longer than 100 bits. These larger error bursts are often deleted from BER calculations as "wild points" because they can be detected and discarded by a computer. They were not discarded in these calculations; if they had been, the BER would have been substantially better.

As the simulated cold mission was originally defined and executed, the recorded data BER exceeded the limit of one in one million. During the cold soak, the magnetic tape apparently reached a temperature below the manufacturer's specified limits ($4^{\circ}C$), and error bursts appeared as drop outs in the recorded data. This was caused by tape compliance changes and/or by moisture condensed and frozen within the tape. The recorder heater cannot re-heat the total mass of the take reel before operation. The data shows both the inside and outside of the tape operated properly; but, the center portion, the last to heat, contained an abnormally high number of errors. This reemphasizes the fact that magnetic tape must be handled with care if proper results are to be obtained. The cold soak time was reduced to 16 minutes without power to the recorder. With this change, the final run of the cold mission provided an acceptable BER.

Recording digital data on Track 1 was not considered part of this test. However, two reproduce runs were made of the 120 ips hot

mission from Track 1 data just to provide a "feel" for its capability. This information was obtained from raw data. BER's are:

Mission Phase	BER x 10^6 Run 1	Run 2
Take Off	0.90	0.63
Low Altitude Cruise	0.08	0.13
High Altitude Cruise	1.00	1.20
Landing	1.00	0.82
Overall	0.70	0.72

These error rates are quite good and Track 1 was often used; it is recommended that the innermost tracks be used to obtain best BER's.

b. Analysis of Test Results - 1-7/8 ips

Since at 1-7/8 ips the available record time is eight hours, the entire mission was recorded. The BER for each 100 feet of recorded tape and for two runs of each track are summarized in Table 10. Two 100 foot increments have a BER in excess of the limit of one error in one million bits; Track 13 at 300 - 400 feet, and again at 500 - 600 feet.

A second look at the 300 - 400 area provided a BER within limits. Thus, the data was recorded on tape, but the reproduce signal-to-noise ratio was low. Note that for this worst increment of tape, the error rate was only 1.4 errors per million bits. The overall mission rate was 0.06 per million bits. The largest error burst was 44 bits.

During the last two days of testing, an oscillation occurred intermittently in the playback system of the Honeywell Model 96. This was particularly bothersome in reproducing data from the 10 March mission, cold cycle. Several steps were taken to eliminate this problem. The following day a cold mission was re-run and the oscillation returned. Although the data of 10 March 1982 is not considered valid, (too many errors), it is interesting to compare it with data taken under disturbance-free conditions. Table 11 gives errors per 100 feet for each track before and after the oscillation was temporarily corrected. The average BER before and after the disturbance correction was 0.34 in one million and 0.055 in one million, respectively. Both are quite good, but there was a factor of six improvement when the disturbance was removed.

TABLE 11

REPRODUCE ERROR COMPARISON BEFORE AND AFTER OSCILLATION CORRECTION

COLD MISSION - 1-7/8 ips

TOTAL ERRORS PER 100 FT. BY TRACK

	BEFORE		AFTER			BEFORE		AFTER		BEFORE		AFTER
TRACK	3	3	3	3	3	13	13	13	13	15	15	15
100-200	60	2	0	0	0	1	0	27	25	0	0	0
200-300	8	16	3	0	0	0	0	0	0	0	0	0
300-400	8	10	0	0	0	0	0	0	0	0	0	0
400-500	0	0	0	0	0	0	0	0	0	0	0	0
500-600	0	0	0	1	1	0	0	0	0	0	0	0
600-700	4	3	0	0	0	0	0	0	0	0	0	0
700-800	15	11	2	1	5	0	1	0	0	0	0	0
800-900	0	4	0	0	9	0	0	0	0	0	0	0
900-1000	140	122	8	8	0	69	59	0	0	63	51	6
1000-1100	7	3	0	0	0	0	0	0	0	0	0	0
1100-1200	64	150	0	2	0	0	0	0	0	0	0	0
1200-1300	1	0	0	0	0	0	0	29	0	0	0	0
1300-1400	8	0	0	0	0	213	86	0	30	2	0	0
1400-1500	0	0	0	0	0	3	4	0	0	0	0	0
1500-1600	0	0	11	23	19	0	0	0	0	0	2	0
1600-1700	0	0	0	0	0	1	0	0	0	0	0	0
1700-1800	0	0	0	0	0	0	0	0	0	0	0	0
1800-1900	0	0	0	0	0	0	0	0	0	0	0	0
1900-2000	0	0	0	0	0	20	0	0	0	0	0	0
2000-2100	0	25	0	0	0	0	0	0	3	0	0	0

OVERALL BER

Before Correction = 3.4 in 10^7

After Correction = 5.5 in 10^8

SECTION VI

CONCLUSIONS

1. SUMMARY

The only situation where poor quality data was recorded was when the recorder and tape were cold soaked for one hour before turn-on. This cold soak allowed water and ice particles to form on the tape, causing a high BER in the center portion of the tape. Discussion between Sangamo, FIBG, and FIEE personnel led to a decision to reduce cold soak time to 20 minutes before recorder power-on stand by. This decision was based on procedures which will be followed during cold environment flight test programs. The tape will remain in heated storage until taken to the aircraft, installed, and tape recorder powered-up to stand by. Twenty minutes is estimated to be sufficient to complete this procedure.

Following this modification, the system functioned satisfactorily. Therefore, it is concluded that the SABRE XII for these types of environments and with good HDDR magnetic tape, a BER of one in one million or less will be achieved.

2. CONCLUSIONS

The tests verify that the Sangamo SABRE XII can record hi-density digital pulse code modulation data in an airborne unconditioned environment. Precautions must be taken with magnetic tape in cold weather.

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APPENDIX

VIBRATION CONTROL

VIBRATION CONTROL

Vibration simulation on CERT tests is accomplished by means of digital computer controllers. In general the aircraft mission profile is segmented into various phases representing take-off and landing, cruise, and combat. The phases of flight have vibration spectra generated from empirical data or predicted by computer analysis. Generally two vibration spectra are utilized to represent a total mission profile.

Putting these spectra into the vibration controller as control inputs is a simple matter; but the computer software does not allow for automatic transition from one spectrum shape to another. Thus, periods occur in the mission when there is no vibration. This situation required an operator to interface with the controller. This also forces the test engineer to minimize the number of vibration spectra which detract from realistic simulation.

The Scientific-Atlanta Model SD1200 digital shaker control and analysis system was available for the Sangamo SABRE XII Test. This controller makes it possible to continuously vibrate a piece of equipment automatically transitioning from one spectrum to another. This allows a realistic simulation of aircraft vibration under constant equilization control.

With this controller, up to 99 different vibration spectra can be obtained. This allows better representation of the vibration environment experienced during the aircraft mission. During combat situations, a transition from a buffet vibration to a low altitude cruise can occur in a matter of five minutes. With past equipment, this could not be simulated due to the time required to enter a new spectrum and equalize to test level. The result was that buffet time would be lumped into an extended period instead of short periods alternating with cruise vibration.

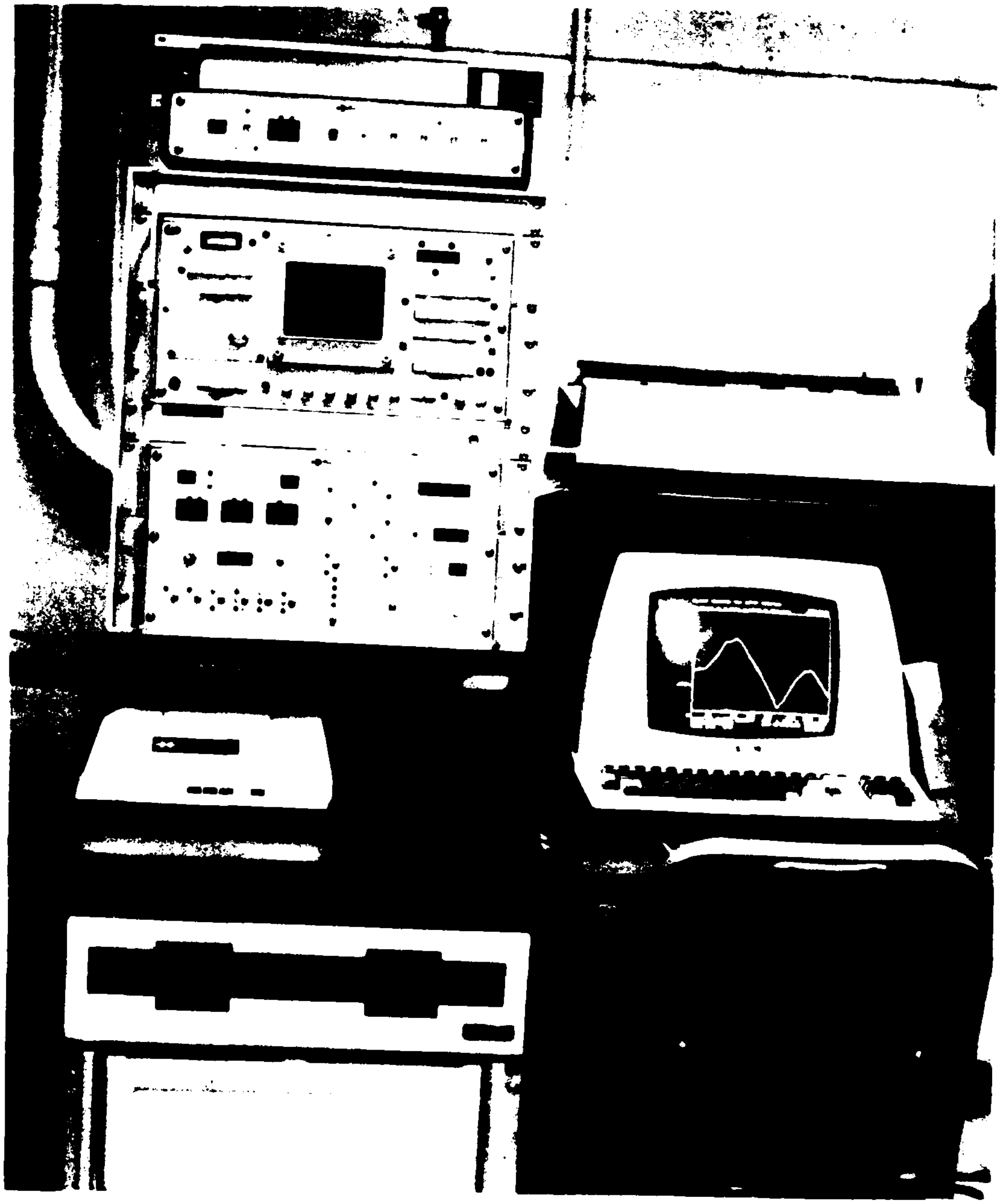

Figure A-1. Spectral Dynamics Vibration Control System

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